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The application of high-density resistivity method in organic pollution survey of groundwater and Soil

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Abstract

The groundwater and soil of Nanjing 1211 Chemical Plant were investigated by the method of high-density resistivity after the plant closure. The results show that there are high resistance anomaly areas of aquifer and soil between 17 and 45 meters where the resistivity is higher than 100 ohm-m. Chemical analyses show that the high resistance anomaly areas are caused by DNAPLs pollution. The spatial distribution of underground pollutants was delineated and the origin of the contaminants was confirmed. The research shows that high-density resistivity method is effective in locating heavy organic pollution of groundwater and soil of chemical plants. The method is both economical and convenient to detect organic pollution and is recommended for such usage.

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Key words: high-density resistivity method, groundwater, soil, organic pollution, pollution halo

1. Introduction

Nanjing 1211 Chemical Plant was established in the 1940s on an area covering 1 km^2, and is now closed. The raw materials used in the plant included benzene, nitrobenzene, aniline, chlorobenzene, hydrochloric acid, and the primary products were aniline hydrochloride, o-nitrobenzaldehyde, dicyclopentadiene-co-p-creso, l,2-tert-butyl-4-methylphenol, rubber auxiliary and chloro-alkaline. The potential pollution of groundwater and soil of the plant is of great concern to the local government because it has direct responsibility for land development and utilization. It is clear that finding out the organic pollution condition of the groundwater and soil of the site is of fundamental importance.

2. Geological Setting

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The site is located in an "U" type small plain with north gentle dip and its east side, south side and west side are hills with altitude between ten to dozens of meter while the north side is a river. The geologic section from bottom to top in the study area is: (1) Upper Cretaceous Pukou group with general depths below 40-50 meters and purplish-red or gray-yellow sandy conglomerate. (2) Pleistocene series Xiashu group loess with depth of 12-40 meters and multilayers of silty clay with interlayer of silt and sand. The bottom of Xiashu group loess is a gravel layer and it is in discordant contact with the bedrock of upper Cretaceous Pukou group. (3) Holocene series overly the Xiashu group and are composed of silt and silty clay overlain by fluvial Quaternary unconsolidated sediments and soil in the top10 to 12 meters.

The aquifer can be divided into a phreatic water aquifer and a micro confined water aquifer. The thickness of the phreatic water aquifer is 5 to 6 meters and the aquifer is constituted by silt clay with thin interlayer of fine sand, and fine sand and silt while the micro confined water aquifer occurs in thin layers of fine sand, medium sand in Pleistocene series of silty clay and residues of bedrock surface.

3. Method

The method of high-density resistivity is adopted for use in this research. After confirming the abnormal area, drilling and chemical analyses are used to verify the geophysical results. DUK-2 type high-density resistivity detection system, which was used during the study, is a new type detection system developed by Chongqing, China Geological Instrument Plant.

4. Results

The method of high-density resistivity consists in passing direct current into strata to measure the electrical resistivity and to identify the interface between different materials and the measured result is called resistivity profile. The method is used to locate groundwater resources as well as investigate building and dam foundations, karst collapse and mine goaf [1-4]. This method is, more recently, being applied to investigate groundwater pollution [5-8]. There are several electrode arrangements for the method such as Wenner Array (Fig. 1), Schlumberger Array, Pole-Pole Array and Dipole-Dipole Array which are applied during the research. Study results show that the four arrangements can be used to ascertain pollution plume and Schlumberger Array do not express as good as the other three arrays.

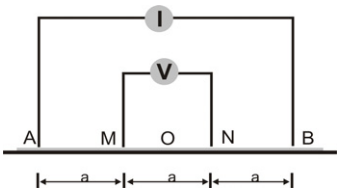

Fig.1. electrode arrangements of Wenner Array (A, B: current electrodes; M, N: potential electrodes; O: midpoint; I: current; V: voltage)

Results of high-density resistivity show that the thickness and depth of phreatic water aquifer is generally 4 to 5 meter and the aquifer is composed of thin layer sand and sandy silt clay with its background resistivity value generally below 20 ohm-m. The top layer of micro confined water aquifer is composed of multilayers of fine and medium sand in the middle Pleistocene series of silty clay at depth from 20 to 26 meters with a background resistivity value generally below 60 ohm-m; the lower strata is constituted by a sandy gravel layer of Cretaceous residues mixed with fine/medium sand at depth from 35 to 42 meter with a background resistivity value generally below 100 ohm-m. The background resistivity

value of stratum that is not polluted is usually below 100 ohm-m, while high resistivity areas with values exceeding 100 ohm-m are commonly associated with residual DNAPLs pollution plume (Fig. 2 and Fig. 3), mainly at depth between 17 and 45 meters.

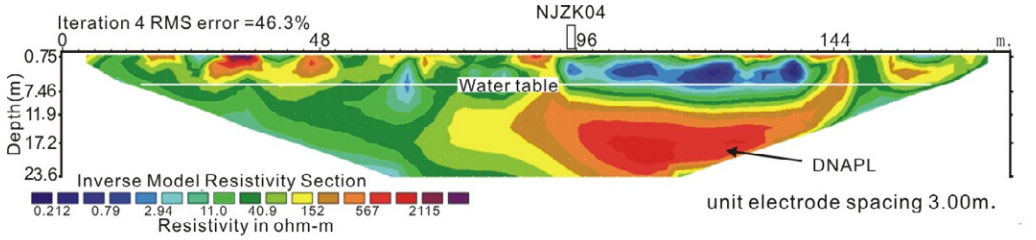

Fig.2. Profile map of Electrical property of measure line X2 (Wenner Array)

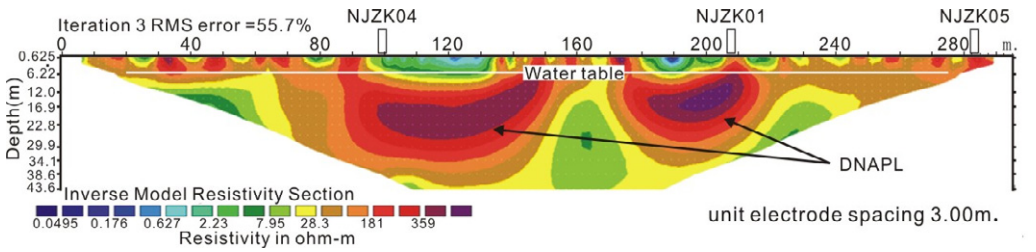

Fig.3. Profile map of Electrical property of measure line X3 (Wenner Array)

Table 1. Concentration of the main pollutants in sediment samples of the 5 drill holes (Units: μg/ kg)

	Hole 1	Hole 2		Hole 4					Hole 5		
Main pollutants	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Aniline	ND	2000	600	1070	1680	7880	1690	430	15800	1830	2300
1, 2-Dichloroethane	ND	1.6	2.3	ND	ND	3.77	ND	ND	ND	ND	ND
Chlorobenzene	3040	4303	450	59.8	2820	12500	37.3	38.9	20100	35.4	4880
Nitrobenzene	1373	920	509	35200	120000	1836000	13600	10200	472000	2000	56200
Methyl chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	562	937.7	125	7.69	37	8980	2.98	1.77	1810	4.39	319
1, 4 – Dichlorobenzene	319	396	43.3	7.3	882	7180	18.1	4.64	12000	6.43	322
1, 2 – Dichlorobenzene	190	238	28.5	4.58	538	4550	14.3	3.27	7240	5.06	197
Ethylbenzene	140	39.3	3	0.71	95.9	1390	0.91	0.68	52.7	0.46	3.46
Dichloromethane	ND	0.7	0.9	1.04	ND	21	0.56	1.17	3.25	0.5	2.6
Chloroform	1.0	0.9	0.3	ND	ND	13	ND	ND	ND	ND	ND
Tetrachloroethylene	0.5	0.5	ND	0.72	0.53	15.4	0.7	ND	4.02	1.06	0.49
Benzo (a) pyrene	47.8	69.9	4.31	ND	3.39	463	ND	4.07	267	46.8	2.33

Results from the five drill holes confirm the presence of contaminants at all the interfaces. The contaminants have consistent strong "bitter apricot kernel" smell and pollutants in the sand are oil

saturated and black. There are a large number of organic pollution components in the groundwater samples and at different depths in the sediment samples (Table 1). The soil samples obtained from drilling contain almost the same pollutants as groundwater, i.e. raw materials and products of chemical plant, which leave no doubt about the origin: a leakage form an underground storage tank.

5. Conclusion

In this study, the contamination status of soil and groundwater in Nanjing 1211 Chemical Plant are ascertained: the origin of pollutants is confirmed and the spatial distribution of underground pollutants is delineated. Results show that the high-density resistivity method is very effective in delineating organic pollution in soil and groundwater. Four kind of array were tested (Wenner Array, Schlumberger Array, Pole-Pole Array and Dipole-Dipole Array) and helped to determine the pollution plume, with better results obtained with the Wenner Array, Pole-Pole Array, and Dipole-Dipole Array.

Results of drilling and testing of groundwater and soil can further confirm the effectiveness and soundness of high-density resistivity method. Moreover, the high-density resistivity method is both economic and convenient to detect underground organic pollution and it is recommended for such usage.

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